

**Preliminary assessment of the interaction of collectivism and the heat-aggression
relationship in terrorism**

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Abstract

Objective: The relationship between heat and aggression is robust for different types of aggressive acts and has been recently extended to terrorism, providing another avenue when examining causes and environmental contributors to political violence. The present study describes a preliminary investigation of the role that cultural factors, such as collectivism, may play in the heat-aggression relationship, specifically as it pertains to terrorist attacks.

Method: Country-level terrorism data from 1970 to 2015 and monthly average temperatures across the same timeframe were integrated with individualism/collectivism ratings from Hofstede's IBM studies and the GLOBE studies and analyzed with zero-truncated negative binomial regression models.

Results: The results indicated that societal in-group collectivism significantly interacted with temperature and counts of terrorist attacks, with higher ratings of in-group collectivism associated with weaker associations between temperature and terrorism. Other collectivism constructs such as Hofstede's individualism-collectivism index and institutional collectivism did not interact with temperature and terrorist acts.

Conclusions: The findings provide initial evidence of the role cultural factors may play in shaping the temperature-aggression relationship as it pertains to terrorism, which may be a major consideration as societies continue to be negatively impacted by climate change.

Keywords: temperature, heat, collectivism, aggression, terrorism

Public Significance Statement: Higher temperatures are associated with more frequent terrorist attacks. Based on data from 1970 to 2015, this research finds that countries with sampled

populations reporting more importance in family and kinship groups are resistant to this temperature-terrorism relationship. These findings imply that cultural values may shape how people react to environmental changes and the experienced personal significance from strong social bonds may help buffer some negative impacts of high temperatures.

Preliminary assessment of the interaction of collectivism and the heat-aggression relationship in terrorism

The sustained increase in average global temperature over the last century has been of significant concern due to its effects on international socioeconomic stability, biodiversity, and heightened risk to human health and well-being (IPCC, 2023). Higher temperatures are associated with a tendency to commit aggressive acts on an individual (Anderson, 2001), small group (Craig et al., 2016), and societal level (Hsiang et al., 2011; 2013) due to psychological factors (DeWall et al., 2011) and adverse socioeconomic pressures and instability (Chassang & Padro-i-Miquel, 2009). Given the risk posed by climate change and the potential contribution of higher temperatures to conflict and harm, understanding and mitigating these effects is of significant theoretical and practical interest (Miles-Novelo & Anderson, 2023). This study examines the boundaries of the seemingly ubiquitous relationship between heat and aggression, particularly considering evidence that higher temperatures correlate with an increased rate of terrorist acts (Craig, Overbeek, & Niedbala, 2021; Price & Elu, 2017). We consider whether cultural factors, specifically collectivism, may influence the relationship between temperature and aggression.

Ambient Temperature and Aggression

Researchers investigating violence have consistently observed an increase in aggressive acts with higher temperatures (Anderson, 1989; Anderson, 2001; Anderson et al., 1997). For example, there are stronger correlations between temperature and violent crime than between temperature and nonviolent crime (Anderson, 1987), suggesting that temperature is associated with committing violent acts. One explanation for the heat-aggression relationship on the individual level utilizes the framework of the General Aggression Model (GAM; Anderson,

2001; Anderson & Bushman, 2002; DeWall et al., 2011). In this framework, individuals in potentially aggressive situations encounter personal inputs (e.g., traits, beliefs) and situational inputs (e.g., environmental cues), which influence internal processes such as cognition, affect, and arousal. These internal states then shape the outcome through an appraisal and decision-making process, which may result in impulsive or deliberate actions, ultimately leading to a new situation.

The heat hypothesis complements GAM by explicitly focusing on temperature as an aggressive cue that causes discomfort and frustration (Anderson, 2001). High temperatures not only increase discomfort but also reduce the mental resources available to inhibit impulsive behaviors (Anderson & Bushman, 2002). This combination of heightened arousal and reduced self-control creates conditions conducive to aggression, such as increasing negative affect and energetic arousal, while subsequently decreasing the mental resources necessary to inhibit impulsive decision-making. Negative affect plays a central role in the relationship between heat and aggression by creating a cascade of emotional and cognitive changes that increase the likelihood of aggressive behavior. As temperatures rise to uncomfortable levels, individuals experience heightened irritability, frustration, and hostility, which are key components of negative affect (Anderson et al., 1997; Meidenbauer et al., 2024). This negative affect intensifies aggressive motives and reduces cognitive resources needed for self-regulation, making it more difficult to inhibit impulsive actions (Anderson & Bushman, 2002). Furthermore, the perception of thermal discomfort amplifies these emotional responses, as individuals who perceive the heat as more uncomfortable are more likely to experience negative affect and subsequent aggression (Meidenbauer et al., 2024).

Significance Quest Theory (SQT) provides a key mediating relationship between negative affect and aggression. SQT indicates that a loss of significance, the fundamental human need to feel valued, plays a major role in violence (Ellenberg, Kruglanski, & Bushman, 2025). When individuals perceive the experience of frustration and negative affect as associated with the loss of personal or in-group significance, there is a higher likelihood of using aggression to prevent said loss or regain significance. The concurrent perception of thermal discomfort can heighten the experience of frustration in the context of experiencing a perceived loss of significance. Furthermore, this SQT mechanism operates within the framework of GAM, as aggression mitigates significance loss when cognitive resources are limited. Thermal discomfort can be distracting, and prolonged exposure to high temperatures disrupts more complex mental performance (Lopez-Sanchez & Hancock, 2018), which is required to inhibit straightforward aggressive impulses and select more complex non-aggressive strategies to mitigate significance loss (Ellenberg et al., 2025). Taken together, these findings underscore the critical role of negative affect in linking high ambient temperatures to increased aggression and violence.

The heat-aggression relationship extends beyond individuals to small and large groups. In group contexts, hotter temperatures correlate with increased aggressive actions in sports. For instance, American football players commit more violent penalties during hotter games (Craig et al., 2016), and similar findings have been observed in baseball games with boundary conditions such as divisional rivalries or seasonal timing (Larrick et al., 2011; Reifman et al., 1991; Krenzer & Splan, 2018). When under threat or stress, individuals tend to identify more strongly with their in-group (Hohman & Hogg, 2011) and exhibit an enhanced willingness to defend their in-group (Hohman & Hogg, 2015). Notably, this enhanced willingness to defend the in-group when under threat was attenuated when individuals were exposed to conditions designed to boost self-

esteem, implying that perceived personal significance plays a role. SQT extends to group aggression by explaining how individuals who strongly identify with their groups may perceive frustrations or threats to the group's significance as justification for violence in certain circumstances. This can occur even when the individual group members committing the violence have not personally experienced a loss of significance (Ellenberg et al., 2025).

On a larger scale, hotter global temperatures are linked to increased civil conflicts (Hsiang et al., 2011). While psychological frameworks such as GAM and SQT help account for individual-level and group-level aggression, an econometric model originally presented by Chassang and Padro-i-Miquel (2009) and extended by Burke, Hsiang, and Miguel (2015) provides a broader account of societal-level violence. The model partially incorporates psychological factors while primarily emphasizing the utility of violence for asset acquisition and the impact of resource availability for a given population density. By demonstrating how rising temperatures exacerbate resource scarcity and reduce economic productivity, this model highlights how these stressors increase intergroup competition and conflict. Rising temperatures worsen economic productivity, especially in agriculture and labor-intensive sectors. This creates resource scarcity, unemployment, and poverty, leading to widespread socioeconomic instability. The reduction of scarce socio-economic resources thereby reduces the psychological cost of committing violent acts (Burke et al., 2015).

Besides psychological and economic accounts of temperature effects on aggression, temperature also shapes the culture of societies towards more or less aggression over time. The CLASH model claims that populations living in colder climates, particularly those with predictable yet variable seasonal temperatures, tend to develop slower living strategies and increasingly emphasize future orientation and self-control through resource allocation practices,

as those strategies are a better fit for these colder, changing, yet predictable environments (Van Lange, Rinderu, & Bushman, 2017). In contrast, hotter, unpredictable climates may foster cultures oriented more toward faster living strategies, reduced self-regulation, and increased susceptibility to aggressive conflict.

Temperature and Terrorism

While aggression is often impulsive and emotionally driven, terrorism typically involves instrumental violence carried out with strategic intent (Pape, 2003). Despite these differences, environmental factors such as temperature influence the underlying psychological mechanisms shared by both forms of violence. For instance, high temperatures exacerbate key drivers of aggression, such as heightened arousal, impaired self-regulation, and increased negative affect, and similarly intensify the psychological conditions conducive to radicalization and terrorist activity (Anderson & Bushman, 2002; Meidenbauer et al., 2024). Furthermore, the frustration-aggression hypothesis suggests that environmental stressors like heat can amplify feelings of frustration and hostility. When coupled with a loss of significance or perceived injustice, this amplified negative affect may push individuals toward violent acts, including terrorism (Ellenberg et al., 2025; Kruglanski et al., 2019). These shared mechanisms provide a conceptual bridge between the heat-aggression relationship and the more complex phenomenon of terrorism.

Price and Elu (2017) noted that hotter temperatures are associated with reduced psychological costs of committing violence, consistent with the theoretical model advanced by Burke and colleagues (2015). Analyzing whether temperature change and other factors, such as rainfall, may contribute to the likelihood of terrorism, Price and Elu (2017) demonstrated with state-level data that higher temperatures increased the probability of terrorism in Nigeria. Craig and colleagues (2021) used a similar approach on a global scale, examining country-level data

from 159 countries to assess the relationship between temperature, terrorist acts, and terrorism-related deaths. A temperature-aggression relationship was found for both terrorist acts and fatalities, even when controlling for the potentially confounding factors of summer months (e.g., summer travel) and time (e.g., increased terrorism over time). Those studies provide reasonable evidence of a relationship between temperature and terrorist acts at both the state and country levels.

While there is evidence that the rate of terrorist attacks increases with higher temperatures, a deeper understanding of this phenomenon requires exploring the mechanisms that lead an individual to become radicalized into engaging in terrorist acts. One comprehensive model that explains these individual motives and social dynamics is the 3N model of radicalization, which can help bridge the gap between environmental triggers like temperature and the complex psychological processes that lead to individuals engaging in terrorist activities.

Terrorism and the 3N Model of Radicalization

The 3N model of radicalization (Kruglanski et al., 2019) offers a comprehensive framework for understanding how individuals become radicalized and engage in terrorist acts. Specifically, the model identifies the three core psychological needs that drive individuals toward terrorism: the need for significance, a narrative advocating violence, and social networks endorsing that narrative. Additionally, societal and cultural factors can influence these needs. Here, given their relevance to the study, we focus on two of the three needs in the 3N model.

Need for significance. Pursuing significance is central to the 3N model and is a fundamental motivational driver behind radicalization. This need refers to individuals' desires to feel important, respected, and valued within their social environment (Kruglanski et al., 2019). They are more likely to become radicalized when that desire is unmet and made salient either

through experiences of humiliation, marginalization, or powerlessness (significance loss) or by opportunities to achieve respect or recognition through violent acts (significance gain; Kruglanski et al., 2022). Terrorist organizations often exploit these vulnerabilities by offering individuals a path to restore or enhance their significance through extremist actions. Research on aggression supports this notion, showing that frustration or powerlessness can lead to aggressive behaviors when individuals seek to regain control or status (Anderson & Bushman, 2002).

Need for social networks. Another critical component in the 3N model is the role of social networks in facilitating radicalization. Social ties provide emotional support, validation of extremist beliefs, and access to resources necessary for violent action (Kruglanski et al., 2019). These networks validate and reinforce violence-justifying narratives while offering social recognition to those who act on behalf of the cause. For instance, participants in violent acts such as the storming of the U.S. Capitol received praise from their social networks, further validating their actions (Kruglanski et al., 2022). Research shows that radicalization rarely occurs in isolation but is facilitated by peer groups or online communities that reinforce extremist ideologies (Anderson & Bushman, 2002; Moskalenko & McCauley, 2011).

Collectivism

High-temperature environments may increase the likelihood of reacting aggressively to losses in group significance, either via increased frustration or cognitive load, disrupted economic stability, or reduced psychological costs of violence due to increased scarcity. An example of inter-group violence is terrorism. Terrorists become radicalized when their need for significance interacts with a violence-justifying narrative that is endorsed and validated by their social network.

Cultural variables influencing these relationships may also influence the temperature-aggression relationship with terrorist acts. One such potential cultural variable is collectivism, which refers to how individuals in a society are integrated into strong, cohesive groups and prioritize collective goals over individual interests (Hofstede, 1980; 2001). It prioritizes interdependence, group harmony, and shared responsibility among collective members. Members of collectivist cultures often exhibit loyalty to their in-group, such as family or close-knit organizations, and this loyalty typically takes precedence over personal desires or ambitions (Hofstede, 2001). Furthermore, collectivism is not a single individual-level construct but rather operates at the personal, organizational, and societal levels and can apply to kin groups, non-kin in-groups (e.g., religious, national, and ethnic affiliations), and non-personal structures such as institutions (House et al., 2004). These dimensions highlight that while collectivist cultures emphasize collective interests, they likely operate through diverse mechanisms and produce different behavioral outcomes. Here, we consider three related but distinct conceptualizations of collectivism.

Individualism-collectivism (Hofstede, 1980; 2001). Hofstede's cultural dimensions were measured by surveys of workers within IBM, a company with offices worldwide, to describe cultural attitudes within large-scale organizations in different countries. These attitudes arguably reflect cultural values within those countries. The individualism-collectivism construct characterizes the relationship between individuals and the organization to which they belong, with more collectivist societies tending towards emotional interdependence between workers and organizations (Hofstede, 2001). Individuals are willing to sacrifice personal time for their organizations, and those organizations are willing to commit resources for the benefit of their

employees in countries low in individualism. The measured strength of these interrelationships is thought to generalize to groups outside of work and occupation.

A key characteristic of this form of individualism-collectivism is its influence on self-control. Individuals internalize the norms and expectations of their close social networks, which fosters a habitual form of self-discipline. This self-control ensures adherence to shared goals and prevents behaviors that could disrupt group cohesion (Oishi & Komiya, 2017). In this context, self-regulation is not only an individual trait but a social necessity, reinforcing group harmony (Geyer & Baumeister, 2005). However, this focus on group harmony often limits adaptability and openness to outsiders. Individuals primarily confine loyalty and trust to the in-group, which hinders broader societal integration or engagement with external opportunities (Yamagishi, Jin, & Miller, 1998). As such, while collectivism promotes strong internal cohesion, it may also foster distrust of outsiders and resistance to external influences, particularly in the context of threats to the group or conditions of resource scarcity that heighten intergroup competition (Burke et al., 2015).

In-group collectivism (House et al., 2004). In-group collectivism refers to the degree to which individuals demonstrate pride, loyalty, and cohesiveness within their immediate social networks, such as families or close-knit groups (House et al., 2004). This cultural dimension emphasizes the importance of interpersonal bonds and shared norms that govern behavior within these small, tightly connected groups. Individuals in high in-group collectivist cultures often derive their identity from close relationships and small group memberships, embedding their sense of self within the scope of their immediate social circles (Gelfand et al., 2004).

While this form of collectivism is significantly related to the individualism-collectivism dimension as described by Hofstede (2001), one apparent difference is that whereas the in-group

collectivism construct prioritizes kin-group bonds (Gelfand et al., 2004), the individual-collectivism construct describes the willingness to sacrifice family time for the sake of the broader organization. This distinction may matter because kinship bonds and kinship cooperation are ubiquitous in human societies and likely precede other forms of social cooperation, both on an evolutionary timescale and an individual lifespan (Voorhees, Read, & Gabora, 2020). Therefore, it may be easier for individuals to identify with their families relative to other in-groups.

Institutional collectivism (House et al., 2004). Institutional collectivism is the extent to which institutions prioritize collective action and resource distribution at a societal level (House et al., 2004). Unlike in-group collectivism, which centers on close interpersonal relationships, institutional collectivism emphasizes organizational practices and societal structures that reward collective interests over individual gains. In high institutional collectivism cultures, individuals often derive their identity from their roles within institutions or organizations rather than personal relationships (Javidan et al., 2006). This broader focus enables institutional collectivist cultures to promote long-term societal planning and future-oriented goals, such as infrastructure development, educational systems, and resource management (Brewer & Venaik, 2011). However, these same characteristics may be less effective at providing the emotional support and personal validation that individuals need from social networks. The impersonal nature of institutional collectivism can weaken its ability to address individual psychological needs, such as those for significance or belonging, while reducing inter-group competition by managing resources more equitably.

Effects of Culture on Temperature-Terrorism Relationship

While temperature can shape culture and aggressive tendencies (CLASH; Van Lange et al., 2017), the relationship may be bidirectional. Collectivism may shape how individuals respond to environmental stressors, such as temperature, by influencing psychological processes like self-control and significance-seeking. Low individualism indicates significant interrelationships between people and their organizations. Similarly, in-group collectivism fosters strong interpersonal bonds and emotional support that can buffer against radicalization by fulfilling psychological needs within close-knit networks, particularly kin groups (Hafez & Mullins, 2015). Institutional collectivism emphasizes broader societal structures that may lack the intimacy needed to address personal feelings of insignificance or alienation (House et al., 2004), yet may better mitigate economic disruptions that tend to exacerbate intergroup conflict and lead to increased societal violence (Burke et al., 2015). Understanding how these cultural orientations interact with environmental factors may provide critical insights into the pathways leading to radicalization and violence.

Collectivism and terrorism. Researchers have examined the relationship between collectivism and other cultural factors on the likelihood, typology, and severity of terrorist acts. These studies have primarily employed Hofstede's measures (e.g., Kluch & Vaux, 2017; Peterka-Benton & Benton, 2014; Wiedenhaefer et al., 2007), although some studies have employed the GLOBE measures (Braun & Genkin, 2014; Gelfand et al., 2013). The toleration of terrorist tactics, particularly the use of attacks on civilians, was found to be associated with Hofstede's measure of individualism, with more individualistic populations more likely to strongly reject these attacks (Kluch & Vaux, 2017). Peterka-Benton and Benton (2014) found that more incidents of terrorism were attributed to groups from countries with low individualism, as measured by Hofstede. Wiedenhaefer and colleagues (2007) observed a weak relationship

between Hofstede's measure of individualism and the rate of terrorist attacks within a country, with countries with higher individualism scores reporting slightly fewer attacks by long-term nationals. Kluch and Vaux (2017) did not find a relationship between Hofstede's individualism in a given country and the likelihood of terrorist attacks, but they did observe that low individualism was associated with lower attack fatalities. Braun and Genkin (2014), using a composite measure of collectivism, found that terrorist organizations estimated as scoring higher on their collectivism measure were more likely to employ suicide bombings. Finally, Gelfand and colleagues (2013) found that the GLOBE measure of in-group collectivism practices was not associated with the number of terrorist incidents or fatalities within a country.

The Present Study

The goal of this study was to explore whether cultural factors such as collectivism can influence the heat-aggression relationship, with acts of terrorism as the outcome measure of interest. Collectivism fosters stronger in-group bonds, leading individuals to define themselves through intragroup relationships (Gelfand et al., 2004), so when the in-group is under threat, this may lead to an increased willingness to defend the in-group (Hohman & Hogg, 2015) and commit aggression (Ellenberg et al., 2025). There is some evidence that this is the case when estimating the cultural attitudes of terrorist groups that have committed attacks (Braun & Genkin, 2014). However, measurements of cultural dimensions for a country are thought to index the cultural values of the dominant culture of that country unless the sampling specifically targets a subculture (Hofstede et al., 2010). Attacking terrorists are likely culturally out-group members of the attacked country, especially in collectivist countries. Higher collectivism of the dominant culture of the country should be protective for most people in that country in terms of reducing radicalization and violence against the country, due to economic and psychological stressors

caused by increasing temperatures. The proposed mechanisms are increased self-control via social support, socially ingrained self-discipline, and a strong sense of significance via in-group networks, obviating the temptation to seek significance through violence. The social cohesion and interdependence provided by a greater degree of collectivism could potentially reduce the likelihood of terrorist radicalization by providing alternative means of meeting needs for significance and social network support (Kruglanski et al., 2019). Stressors induced by heat and conflict may be less effective at eroding self-control and at undermining personal significance when personal significance is supported by tighter social bonds (Ellenberg et al., 2025).

We predicted that the positive relationship between temperature and terrorist acts previously observed by Craig and colleagues (2021) would interact with the degree of collectivism practiced within the society in which potential terrorist incidents take place. Given this prediction, we made the following hypotheses: (1) We hypothesized that higher scores on the Individualism index (Hofstede, 2001) would significantly interact with temperature and terrorism, with lower scores in the index reducing the strength of the temperature-terrorism relationship within a given country. (2) Given the importance of in-group relationships and economic stability to the likelihood of endorsing violence, we also hypothesized that higher scores on measurements of societal in-group collectivism in practice (House et al., 2004) would weaken the relationship between temperature and the likelihood of terrorist acts. (3) We hypothesized a similar but weaker interaction effect for measurements of societal institutional collectivism in practice (House et al., 2004) on temperature and the likelihood of terrorist acts, given the role that resource scarcity and economic stress may play in instigating intergroup conflict (Burke et al., 2015) and how equitable distribution of limited resources to the community could mitigate this source of conflict.

Method

We partially replicated the analysis presented by Craig and colleagues (2021, which examined temperature and terrorism data from 1970 to 2015. Temperature data were retrieved from the Global Historical Climatology Network database, updated to 2015 (Lawrimore et al., 2011). Terrorism data were retrieved from a database maintained by the National Consortium for the Study of Terrorism and Responses to Terrorism (i.e., Global Terrorism Database; GTD) (START, 2022). We integrated this dataset with collectivism data compiled for 72 countries. Publicly available cultural variable data related to collectivism were retrieved from two separate sources. The Individualism index scores for 61 countries were taken from Hofstede (n.d.). Institutional collectivism and in-group collectivism (i.e., family collectivism, see Brewer & Venaik, 2011) scores for 50 countries were taken from GLOBE (2020). National population data were retrieved from the United Nations, Department of Economic and Social Affairs, Population Division (United Nations, 2015) and the World Bank, World Development Indicators (World Bank, n.d.). This study is a secondary data analysis, and any achievable sample size is contingent on the available archival data.

The collectivism data sources have scores for more countries than were analyzed here, as a few countries were excluded from this analysis, specifically Canada, Czech Republic, United Kingdom, Germany, Iran, Russia, and South Africa. In some cases, borders changed across time periods (e.g., East/West Germany) or were not measured consistently (England vs. United Kingdom), and in other cases measurements were provided for subsets of groups within a country and not the whole country (e.g., racial subgroups in South Africa). Because country-level data are already relatively imprecise, we did not want to introduce further imprecision in

our measurements of cultural variables, even if this might come at the cost of statistical power. Please refer to the Appendix for a list of countries in the following analyses.

Measures

Terrorist acts were measured as the number of attacks per month for a given country. Temperature data were analyzed as the mean monthly temperature in Celsius for a given country. Please refer to Craig et al (2021) for more details on sources. Variables measuring collectivism included an Individualism Index (Hofstede, 2001), and two societal measures of collectivism in practice for in-group (family) collectivism and institutional collectivism (House et al., 2004). National population data for the corresponding country per year was an estimated count (United Nations, 2015; World Bank, n.d.).

Individualism index (Hofstede et al., 2010). This index reflects previously standardized country-wide mean scores for a set of six out of fourteen work goal questions originally disseminated to IBM employees across 53 countries with high factor loadings on a factor identified as Individualism. The scores were transformed into a range of 0 to 100, with higher scores representing individualism and lower scores representing collectivism. The work goal questions most associated with the individualism factor were the level of importance placed on having a job with sufficient time for personal or family life (positively related) and the level of importance of a job that had training opportunities to improve or learn new skills (negatively related). The retrieved data represent the scores presented by Hofstede and colleagues (2010), provided by Hofstede (n.d.).

In-group collectivism practices (House et al., 2004). The in-group collectivism measures used here were intended to reflect participant perceptions of the current prevalence of a behavior

or state of affairs focused on in-group collectivism (e.g., the relationship between parents and children) at the societal level (i.e., “In this society...”) assessed with two questions on a 7-pt scale. The retrieved data was collected from GLOBE (2020).

Institutional collectivism practices (House et al., 2004). The institutional collectivism measures used here were intended to reflect participant perceptions of the current prevalence of a behavior or situation focused on institutional collectivism (e.g., group loyalty, individual goals, and collective interests) at the societal level (i.e., “In this society...”) assessed with two questions on a 7-pt scale. The retrieved data was collected from GLOBE (2020).

Temperature. Temperature data in degrees Celsius were retrieved from the quality-control-adjusted dataset by the Global Historical Climatology Network - Monthly (GHCN-M), Version 3 (Lawrimore et al., 2011). The dataset provides monthly mean land surface temperatures for 7,280 weather stations in 226 countries and territories. The monthly temperature data were averaged across stations within each of the 159 countries for which we had corresponding terrorism data between 1970 and 2015.

Analysis

The unit of analysis for the key variables of temperature and terrorist attacks was per month. Given the absence of terrorist attacks in some countries for certain months and years, we analyzed the data with truncated negative binomial regression models with zero as the truncation point. We used cluster-robust standard errors to account for error correlations across multiple variables with a modification of the command file used by Cameron and colleagues (2011). All analyses were conducted with STATA version 13. The analyses regressed attacks per month on

one of the collectivism variables and/or temperature. More details on the analysis approach can be found in Craig et al (2021).

Results

Descriptive statistics are presented in Table 1.

[Insert Table 1 here]

The relationship between the Individualism index and number of attacks was significant and negative (IRR = 0.961, $b = -0.04$, $Z = -4.11$, $p < .001$). That means a higher score on the Individualism index predicts fewer attacks. No other relationship was significant. See Table 2.

[Insert Table 2 here]

Separate analyses were run to include an interaction term for the cultural variable of interest and temperature on the number of terrorist attacks. For the model with the in-group collectivism measure, the main effects of in-group collectivism (IRR = 2.793, $b = 1.027$, $Z = 2.55$, $p = .011$) and temperature (IRR = 1.558, $b = .443$, $Z = 2.94$, $p = .003$) on terrorist attacks were both significant and positive. The interaction between temperature and in-group collectivism was significant and negative (IRR = 0.933, $b = -0.069$, $Z = -2.72$, $p = .006$). That means terrorist attacks increase as temperature and in-group collectivism increase, and the magnitude of the effect of temperature on attacks decreases as in-group collectivism increases. No other interactions were significant in the other models. See Table 3.

[Insert Table 3 here]

The significant interaction between in-group collectivism and temperature was explored by examining the effect of temperature on terrorist attacks at different levels of in-group collectivism. The simple slopes are presented in Table 4. An increase in in-group collectivism scores was associated with a reduced association between temperature and terrorist acts. This interaction is visually presented in Figure 1.

[Insert Table 4 here]

[Insert Figure 1 here]

Discussion

This analysis aimed to examine the role that cultural factors, specifically collectivism, may play in shaping the heat-aggression relationship. We tentatively hypothesized that collectivism within the broader society of a country would interact with average ambient temperature to predict the number of terrorist attacks. This was based on the economic utility model (Burke et al., 2015), the Quest for Significance theory as it pertains to aggression (Ellenberg et al., 2025), both of which incorporate elements of the general aggression model (GAM; Anderson & Bushman, 2002), and the 3N model of radicalization (Kruglanski et al., 2019). We used the individualism index presented by Hofstede (2001) and the in-group and institutional collectivism in practice measures from House and colleagues (2004) to test our hypothesis on the 45-year temperature (Lawrimore et al., 2011) and terrorism dataset (START, 2022) previously analyzed by Craig and colleagues (2021).

The results partially supported our hypotheses. They found that the individualism index had a significant negative relationship with the number of terrorist attacks, replicating prior research (Peterka-Benton & Benton, 2014; Wiedenhaefer et al., 2007). No direct relationship was

found with the GLOBE collectivism measures for the number of terrorist attacks, consistent with prior research (Gelfand et al., 2013). The second research hypothesis was supported, in that the in-group collectivism measure significantly interacted with average ambient temperature to predict the number of terrorist attacks. The first and third research hypotheses were not supported, as neither the individualism nor institutional collectivism measures interacted with temperature and count of terrorist attacks. The direction of the interaction and an examination of the simple slopes indicated that for lower scores of in-group collectivism, the magnitude of the relationship between temperature and terrorist attack frequency increased. Conversely, for higher scores of in-group collectivism, the relationship between temperature and the terrorism variable became non-significant.

In-group collectivism appears to moderate the relationship between temperature and terrorism, while institutional collectivism does not. Specifically, in-group collectivism, emphasizing strong interpersonal bonds and harmony within kin groups, may buffer the effects of high temperatures typically associated with increased aggression and violence. In contrast, institutional collectivism, which prioritizes alignment with broader societal structures rather than close interpersonal relationships, may not engage similarly with the mechanisms underlying the temperature-aggression effect. Furthermore, the construct measured by the individualism index, which reflects allegiance to businesses at the organizational level and the (un)importance of personal and family time, may not be the form of collectivism that provides a protective effect in suppressing the influence of high temperatures on terrorism (Craig et al., 2021).

Potential Mechanisms for In-Group Collectivism Interaction

The finding that in-group collectivism interacts with the effect of average ambient temperature on the number of terrorist attacks suggests that strong social bonds and emotional

interdependence may serve to mitigate the impact of the psychological stressors associated with high temperatures, including promoting violent behavior and terrorism. While heat impairs cognitive functioning and increases hostile affect (Anderson & Bushman, 2002; Miles-Novelo & Anderson, 2023), in-group collectivist cultures may provide emotional support and social validation within kin groups that counteract these effects, reducing the likelihood of aggression or radicalization. These cultures also promote self-restraint to maintain group cohesion (Li et al., 2018). Increased self-control may help individuals regulate impulsive behaviors triggered by heat, and the collective prioritization of group goals over individual grievances may redirect potential aggression into nonviolent conflict resolution. By fostering strong interpersonal connections and resilient self-restraint, in-group collectivism appears to create a social environment that mitigates the effects of heat on aggression and violence.

Within the context of radicalization and the 3N Model, the moderating effect of in-group collectivism on temperature-related terrorism may operate through enhanced self-control mechanisms that help regulate the quest for significance and the need for social networks (Anderson & Bushman, 2002; Ellenberg et al., 2025; Kruglanski et al., 2022). The internalization of group norms and expectations in tight-knit collectivistic groups fosters habitual self-discipline. In turn, that helps individuals resist impulsive decisions to engage in terrorist acts, even as heat-induced stress might otherwise activate an urgent quest for significance (DeWall et al., 2011). The close emotional bonds and mutual obligations characteristic of in-group collectivism may also provide immediate validation and perceptions of self-significance, reducing the likelihood that individuals will seek significance through violent extremism (Kruglanski et al., 2019).

Given the need for social networks (Kruglanski et al., 2022) and the present results showing that in-group collectivism had an observed interaction with temperature while

institutional collectivism did not, this may illustrate how different social structures influence terroristic actions (House et al., 2004). In-group collectivistic cultures foster deep emotional connections that provide validation through close social relationships. These tight-knit social networks appear more effective at preventing radicalization than the broader but weaker social ties promoted by institutional collectivism (Kruglanski et al., 2022). The network's power is more effective in this respect when operating through close interpersonal relationships rather than abstract institutional structures (Moskalenko & McCauley, 2011).

Additionally, as Ellenberg and colleagues (2025) highlight, networks not only validate narratives but also serve as critical sources of significance for their members. When individuals experience a loss of significance or become disillusioned with their current network, they may seek alternative sources of significance to fulfill this fundamental need. Substituting prosocial networks or activities can mitigate the risk of radicalization or aggression by offering nonviolent pathways to restore significance (Kruglanski et al., 2019). If these prosocial networks are kin groups in a collectivist culture, they may be more likely to be highly available and retrievable as a source of significance (identity salience; Swets & Serpe, 2013) even in circumstances of reduced cognitive capacity (i.e., high heat), relative to other prosocial networks. If true, this may explain why in-group (family) collectivism interacts with and mitigates the temperature-aggression relationship while other types of collectivism do not have a similar effect.

Institutional Collectivism

Institutional collectivism was not found to interact with the temperature-terrorism relationship. The absence of a significant interaction may be due to its focus on broader societal structures rather than close interpersonal relationships. While institutional collectivism emphasizes alignment with societal goals and collective action (House et al., 2004), it does not

reflect the importance of intimate emotional support systems as found in in-group collectivist cultures. As a result, individuals in high institutional collectivism societies may still be more vulnerable to cognitive impairments and emotional dysregulation caused by heat (Anderson, 1989). Furthermore, institutional collectivism does not emphasize fostering the same daily self-restraint required to maintain group harmony in smaller, tight-knit networks. Without this emphasis on self-regulation, individuals may be less equipped to resist impulsive behaviors or aggressive responses under high-temperature conditions (Van Lange et al., 2017). If an interaction effect with institutional collectivism is present, it could be detected with greater statistical power or a different operationalization. This analysis suggests that if this potential effect of institutional collectivism is present yet undetected, it is weaker than the interaction effect with in-group collectivism.

Another explanation may be the metric of violence. The acts of violence measured here are terrorist attacks, which are the endpoint of a process of social group dynamics and radicalization (Abrahms, 2008; Kruglanski et al., 2019; 2022). Cultural variables related to social bonds, such as in-group collectivism, may be more associated with outcome measures broadly resulting from social dynamics. Other measurements of violence may be less contingent on social dynamics and more sensitive to economic factors, which could be impacted by climate and mitigated by institutions, including assaults, riots, and self-harm (Burke et al., 2015; 2024). Institutional collectivism may be more associated with those outcome measures.

Individualism Index

The individualism index was negatively associated with the number of terrorist attacks in the initial regression model (Table 2) but did not interact with temperature in the second regression model (Table 3). Hofstede (2001) argued that this measure, although only assessing

organizational culture for IBM workers, should correspond with the wider societal values of the organization's country of operation. A closer examination of the work goal questions comprising the index in Hofstede (2001) indicates that the measurement hinges on whether the job allows for sufficient time for personal and family life, with higher ratings resulting in higher individualism scores. Furthermore, the individualism index is negatively correlated with the power distance index and national wealth (Hofstede, 2001).

Therefore, the individualism index may primarily reflect whether company workers receive reliable emotional support from family members (i.e., kin group), partially measure power distance given the emphasis of organizations over families and personal time, and indirectly assess the impact of economic status, which corresponds with the role that economic instability may play in contributing to violence (Burke et al., 2015). This may account for the significant relationship of the index to terrorist attack counts. However, given the organizational rather than societal focus of the index and its close relationships with constructs relatively disconnected from meaning-making and social network dynamics, it may not be relevant to the temperature-terrorism effect in the way in-group collectivism appears to be.

Limitations

The primary limitation of this investigation is the limited statistical power of the analyses, as the data for the cultural variables comprises a subset of the countries for which we have available terrorism data. Additionally, only one value per collectivism variable is assigned per country, leaving the analyses unable to parse out within-country error for those measures. A related concern is whether the cultural measures could have changed over time, given only one observation per country, as cultures presumably change over time. Furthermore, country-level

data is insufficient for characterizing subcultures and how subculture characteristics relate to terrorism.

However, cultural values and practices change slowly (Hofstede et al., 2010), which allows for an assumption that the measurements should remain relatively consistent over the timescale of years and even a few decades. More temporally and geographically fine-grained cultural data would be invaluable, but is understandably difficult to obtain. With these concerns in mind, and the relatively small magnitude of temperature-aggression and specifically temperature-terrorism effects (Miles-Novelo & Anderson, 2023), this analysis does not rule out the potential for some unobserved yet real interactions between the individualism index or institutional collectivism, temperature, and terrorist attacks.

Future Research Directions

This study examined cultural factors on an organizational and societal level. Future research could consider these factors on a personal or small group level to determine if individuals and groups who adhere to more individualistic or collectivistic orientations exhibit differing patterns of aggression at different temperature ranges. Furthermore, this analysis only considered collectivism. Other cultural dimensions may be relevant, such as power distance, uncertainty avoidance (Wiedenhaefer et al., 2007), and gender egalitarianism (Gelfand et al., 2013). Future or long-term orientation is a cultural variable (House et al., 2004) encompassing psychological constructs such as self-restraint and impulse control implicated in aggressive actions under higher temperatures (van Lange et al., 2017). Also, this study focused on the full temperature spectrum. Future research could investigate whether there is a notable difference in outcomes for countries with moderately hot climates and those with extremely hot climates. Finally, future research should consider other aggression measures besides terrorism to see if

temperature-influenced acts characterized by hostile aggression are more or less affected by these distinct collectivism constructs.

Prevention and Policy Implications

This study should be considered a preliminary investigation into how cultural factors may interact with environmental factors, such as temperature, to affect the likelihood of aggression. Therefore, providing clear prescriptions on policy and prevention strategies is premature. If the findings and proposed mechanisms presented here are validated by future research, there are some practical implications. The first is the identification of subcultures and their overall cultural values, such as in-group collectivism, and the degree to which that subculture and its members perceive the in-group to be under threat or at risk of significance loss. Another consideration is the environmental health and economic factors that may adversely affect the behavior and well-being of a community or subculture, including increasing ambient temperatures. Intervention strategies or counter-terrorism strategies are beyond the scope of this manuscript, but relevant resources can be found elsewhere (Abrahms, 2008).

Conclusion

This research offered a preliminary examination of the role culture may play in the temperature-aggression relationship as it manifests in acts of terrorism. A re-analysis of the START terrorism data across 45 years, originally presented by Craig and colleagues (2021), with the inclusion of related measures of collectivism, found that individualism had a direct association with the number of attacks, and in-group collectivism interacted with the temperature-aggression relationship. Higher levels of in-group collectivism were associated with a weaker relationship between ambient temperature and the number of attacks. Future research

should investigate this relationship with a more robust dataset, different cultural variables, and other aggression measures.

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Table 1*Descriptive statistics*

	<i>N</i>	Min	Median	Max	Mean	<i>SD</i>
Attacks Per Month	13286	1	3	280	8.25	16.19
Monthly Temperature (Celsius)	13286	18.81	20.83	38.63	18.81	8.61
Total Population	2747	0.14	162.92	13760	614.12	1706.5
Individualism	61	6	39	91	43.54	23.99
Institutional Collectivism	50	3.25	4.17	5.22	4.26	0.44
In-Group Collectivism	50	3.53	5.49	6.36	5.2	0.71

Note. Individualism was used in 8,610 observations and both Collectivism measures in 7,128 observations, repeated as necessary for each country. Population values reflect units in the hundred thousands of people, and comprise 2,747 unique yearly estimates for each country, duplicated to match month-year combinations for each country when temperature and attack data was available.

Table 2

Regression models predicting terrorist attacks with individualism, in-group collectivism, and institutional collectivism

Predictor	IRR	b	Z	p	95% CI		N
					LL	UL	
Individualism	0.961	-0.04	-4.11	< 0.001	-0.059	-0.021	8610
In-Group Collectivism	1.536	0.429	0.64	0.523	-0.888	1.747	7128
Institutional Collectivism	0.209	-1.565	-1.65	0.098	-3.421	0.290	7128

Note. All analyses used zero-truncated negative binomial regression models with population as the exposure variable and computed cluster-robust standard errors by clustering over country and year. For Individualism there were 61 countries and 45 years; for In-Group Collectivism and Institutional Collectivism there were 50 countries and 45 years.

Table 3

Regression model predicting terrorist attacks with temperature-individualism, temperature-in-group collectivism, and temperature-institutional collectivism interactions.

Predictor	IRR	b	Z	p	95% CI		N
					LL	UL	
Temperature	1.01	0.01	0.15	0.878	-0.116	0.135	8610
Individualism	0.958	-0.043	-3.09	0.002	-0.070	-0.016	8610
Interaction	1	0	0.42	0.674	-0.002	0.003	8610
Temperature	1.558	0.443	2.94	0.003	0.148	0.738	7128
In-Group	2.793	1.027	2.55	0.011	0.238	1.815	7128
Collectivism							
Interaction	0.933	-0.069	-2.72	0.006	-0.119	-0.019	7128
Temperature	1.502	0.407	1.73	0.083	-0.053	0.866	7128
Institutional	0.974	-0.027	-0.04	0.971	-1.459	1.406	7128
Collectivism							
Interaction	0.924	-0.079	-1.48	0.138	-0.183	0.025	7128

Note. Temperature in °C. All analyses used zero-truncated negative binomial regression models with population as the exposure variable and computed cluster-robust standard errors by clustering over country and year.

Table 4

Simple slopes for regression model predicting terrorist attacks with temperature (°C) at various levels of in-group collectivism.

In-Group Collectivism			Temperature Effect				95 % CI	
Level	Value	IRR	b	SE	Z	p	LL	UL
<i>M - 1 SD</i>	4.65	1.128	0.12	0.044	2.73	0.006	0.034	0.206
<i>M</i>	5.3	1.078	0.075	0.036	2.1	0.036	0.005	0.145
<i>M + 1 SD</i>	5.95	1.03	0.03	0.034	0.87	0.382	-0.037	0.097

Note. These values were calculated from the results of a zero-truncated negative binomial regression model for interactions between temperature and in-group collectivism.

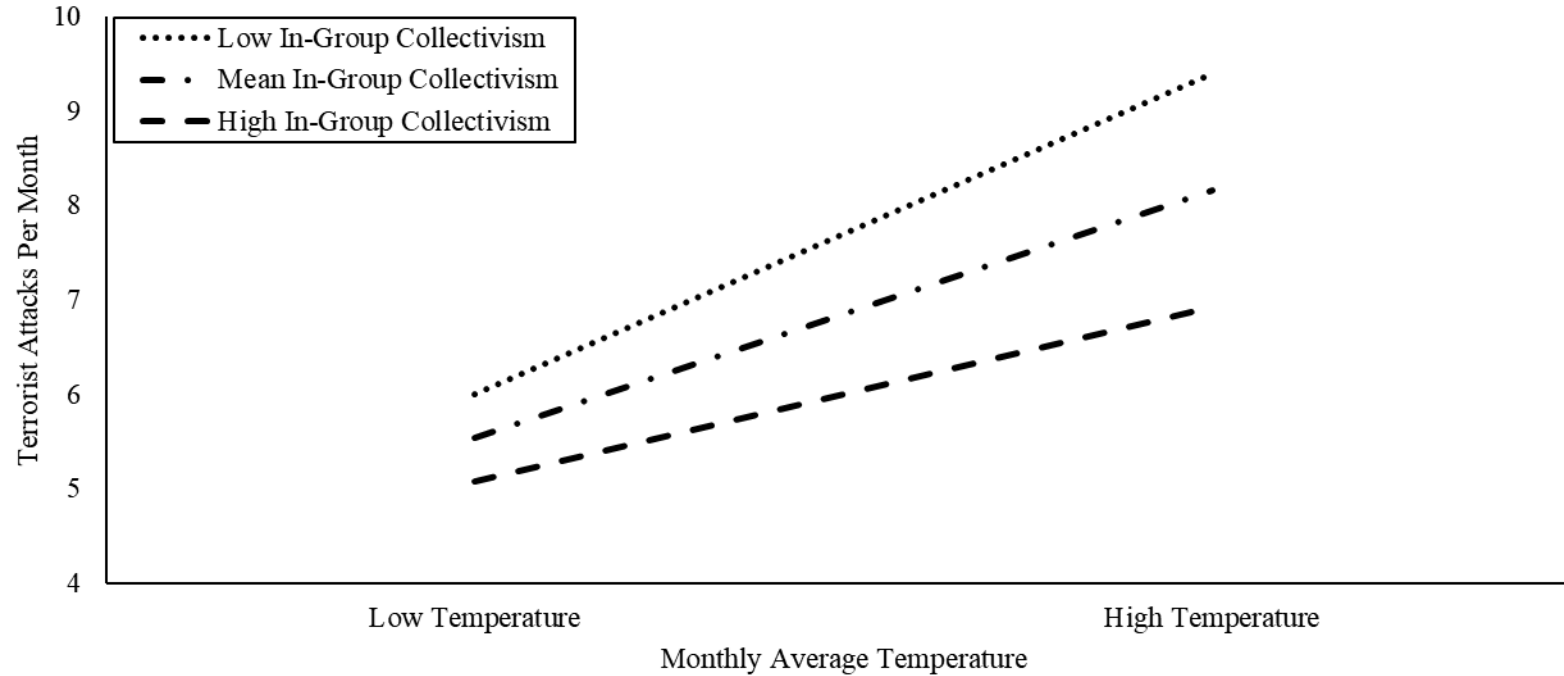


Figure 1. Interaction between temperature and in-group collectivism on terrorist attacks. Low and high temperatures and in-group collectivism represent $M - 1SD$ and $M + 1SD$ respectively. See Table 3 and Table 4 for statistical information. Please note that the minimum value on the y-axis is set to four, not zero.

Appendix

List of countries in dataset

Full Country List with Collectivism Variables: Bangladesh, Belgium, Bulgaria, Canada, Chile, Croatia, Estonia, Germany, Iran, Jamaica, Luxembourg, Malta, Norway, Pakistan, Panama, Peru, Romania, Serbia, South Africa, Suriname, Uruguay, Vietnam, Albania, Bolivia, Egypt, Georgia, Kazakhstan, Kuwait, Namibia, Nigeria, Qatar, Zambia, Zimbabwe, Argentina, Australia, Austria, Brazil, China, Colombia, Costa Rica, Denmark, Ecuador, El Salvador, Finland, France, Greece, Guatemala, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Philippines, Poland, Portugal, Singapore, Slovenia, South Korea, Spain, Sweden, Switzerland, Thailand, Turkey, United States, Venezuela

Both Hofstede and GLOBE (39): Argentina, Australia, Austria, Brazil, China, Colombia, Costa Rica, Denmark, Ecuador, El Salvador, Finland, France, Greece, Guatemala, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Philippines, Poland, Portugal, Singapore, Slovenia, South Korea, Spain, Sweden, Switzerland, Thailand, Turkey, United States, Venezuela

Hofstede only (22): Bangladesh, Belgium, Bulgaria, Canada, Chile, Croatia, Estonia, Germany, Iran, Jamaica, Luxembourg, Malta, Norway, Pakistan, Panama, Peru, Romania, Serbia, South Africa, Suriname, Uruguay, Vietnam

GLOBE only (11): Albania, Bolivia, Egypt, Georgia, Kazakhstan, Kuwait, Namibia, Nigeria, Qatar, Zambia, Zimbabwe